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RESEARCH MEMORANDUM

for the

Civil Aeronautics Administration

DITCHING INVESTIGATION OF A $\frac{1}{15}$-SCALE MODEL

OF THE CONVAIR-LINER AIRPLANE

By Lloyd J. Fisher and William C. Thompson

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

An investigation of a $\frac{1}{15}$-scale dynamically similar model of the Convair-Liner airplane was made in calm water to observe the ditching behavior and determine the safest procedure for making an emergency water landing. Various conditions of damage were simulated to determine the behavior which probably would occur in a full-scale ditching. The behavior of the model was determined from motion-picture records, time-history deceleration records, and visual observations.

It was concluded that the airplane should be ditched at a nose-high attitude of about 9° with the landing flaps full down. The flaps will fail on contact. If they are torn away, the airplane will probably make a smooth run with a maximum deceleration of about 3g. If the flaps rotate toward neutral but are not torn away, the fuselage will run deeper and the maximum deceleration will be about 4g. The fuselage bottom will probably be demaged enough to leak substantially.

INTRODUCTION

A ditching investigation of a model of the Convair-Liner airplane was made to observe the behavior and determine the safest procedure for making an emergency water landing. The ditching model was designed and constructed by the National Advisory Committee for Aeronautics. Design information on the airplane was furnished by the Consolidated Vultee Aircraft Corporation. A three-view drawing of the airplane is shown in figure 1. The investigation was made in calm water at the Langley tank no. 2 monorail.

APPARATUS AND PROCEDURE

Description of Model

The $\frac{1}{15}$-scale dynamic model of the Convair-Liner airplane shown in figure 2 was used in the investigation. It was constructed of balsa wood and spruce and was covered with silk. It was ballasted internally to obtain scale weight and moments of inertia. The model had a wing span of 6.14 feet and an over-all length of 4.98 feet.

The flaps were installed so that they could be held in the down position at approximately scale strength. A calibrated string was fastened between a flap fitting and a corresponding wing fitting so that water loads greater than the ultimate design load (270 lb/sq ft full scale) would cause the string to break. Calibration tests indicated that the string failed within ±10 percent of the desired value. Information furnished on the full-scale airplane concerning the extent of flap failure did not indicate whether the flaps in failing would be free to rotate or be torn from the wing. The initial investigation was made with the flaps attached so that when the string broke the flaps would rotate. Since an undesirable diving moment was produced in this condition, further tests were made with the flaps installed so that when the string broke the flaps became detached from the model.

The effect of damage was investigated by removing some parts and making other parts approximately scale strength. The manufacturer estimated that the full-scale strength of the main landing-gear doors in resistance to water loads was 0.5 pound per square inch. Since this strength is comparatively weak, the doors were expected to be torn away during a ditching and were removed from the model to simulate their failure. Other full-scale strength estimates by the manufacturer were 12 pounds per square inch for the forward under surface of the fuselage and 8 pounds per square inch for the aft under surface of the fuselage. These values indicated a fairly strong construction, so the bottom portion of the model fuselage was replaced by approximately scale-strength sections as shown in figure 3. The scale-strength sections were used to determine whether damage would occur in a ditching and, if so, to indicate its location and extent. The scale-strength bottoms were constructed of cardboard bulkheads and balsa-wood stringers and covered with aluminum foil.

Test Methods and Equipment

The model was ditched by catapulting into the air to permit a free glide onto the water. The model left the launching carriage at scale speed and the desired landing attitude. The control surfaces were set so that the attitude did not change appreciably in flight. The behavior was recorded by a motion-picture camera, from visual observations, and by a single-component time-history accelerometer installed near the center of the passenger compartment. The accelerometer had a natural frequency of 20 cycles per second and was damped to about 65 percent of critical. The reading accuracy of the instrument was $\pm\frac{1}{2}g$.

Test Conditions

(All values are full scale)

Weight.- The design gross weight of 43,500 pounds was simulated in the investigation.

Moments of inertia.- The model was ballasted to obtain the following values of moments of inertia:

Roll, slug-feet^2	158,000
Pitch, slug-feet^2	281,000
Yaw, slug-feet^2	431,000

Center of gravity.- The center of gravity was located at 22 percent of the mean aerodynamic chord and 10.5 inches above the thrust line of the engines.

Landing attitude.- Three landing attitudes were used in the investigation: 9° (near the lift-curve stall angle), 5° (intermediate), and 1° (near static attitude). The attitudes were measured with respect to the fuselage reference line.

Flaps.- Tests were made with the flaps in the up and the full-down positions.

Landing speed.- The landing speeds as computed from lift curves furnished by the manufacturer are listed in table I. The model was airborne when launched and within ±10 miles per hour of these speeds.

Landing gear.- All tests simulated ditchings with the landing gear retracted.

Model configurations.- The model was tested in the following conditions:

(a) No damage simulated, figure 2

(b) Scale-strength bottom sections installed and main landing-gear doors removed, figure 3

RESULTS AND DISCUSSION

A summary of the results of the investigation is presented in table I. The notations used in the table are defined as follows:

Ran deeply - the model moved through the water partially submerged exhibiting a tendency to dive although the attitude did not change appreciably.

Dived - the forward portion of the fuselage and part of the wing submerged and the angle between the water surface and the fuselage reference line was approximately 15°.

Ran smoothly - the model made no apparent oscillation about any axis and gradually settled into the water as the forward speed decreased.

Nosed in - the nose of the model submerged momentarily near the end of the run.

Oscillated - the model oscillated about the longitudinal axis with the motion decreasing as the forward speed decreased.

Trimmed up - the attitude of the model increased immediately after contact with the water.

General

No simulated damage.- The undamaged model with the flaps up ran smoothly at the three attitudes investigated. The maximum longitudinal deceleration was about 4g. When the flaps were down and allowed to rotate toward the neutral position upon failure of the scale-strength connections, an undesirable nose-down moment was produced. The model ran deeply at the 9° attitude and had a maximum longitudinal deceleration of about $1\frac{1}{2}$g. Ditchings at the 5° and 1° attitudes resulted in dives with a maximum longitudinal deceleration of about 6g. When the flaps were down and allowed to become detached from the model upon failure of the scale-strength connections, the model ran smoothly at the 9° and 5° landing attitudes, and had a maximum longitudinal deceleration of about $1\frac{1}{2}$g. At the 1° attitude the model trimmed up and ran smoothly, and the maximum longitudinal deceleration was about 5g.

Simulated damage.- With the main landing-gear doors removed, scale-strength fuselage bottoms installed, and the flaps up the model ran smoothly at the 9° landing attitude; the maximum longitudinal deceleration was about 6g (fig. 4(a)) and the total length of run was about 300 feet. Typical damage which occurred at this condition is shown in figure 5(a).

With the flaps down and allowed to rotate toward the neutral position when the scale-strength flap connections failed, the model ran smoothly but deeply and nosed in at the end of the run. There was a relatively large amount of spray over the model throughout the run which is shown in the sequence photographs in figure 6(a). The total length of run was about 200 feet, and the maximum longitudinal deceleration was about 4g (fig. 4(b)). The bottom of the fuselage was usually damaged somewhat as shown in figure 5(b).

With the flaps down and allowed to become detached from the model when the scale-strength flap connections failed, the model ran smoothly and the total length of run was about 300 feet. There was relatively light spray over the model during most of the run which is shown in the sequence photographs in figure 6(b). The maximum longitudinal deceleration was about 3g (fig. 4(c)). Typical damage to the scale-strength fuselage bottom is shown in figure 5(c). The amount of damage was about the same at both conditions of flap failure.

Ditchings at the 5° landing attitude were somewhat like those at the 9° attitude except that the behavior was more violent and longitudinal decelerations up to 8g were encountered with the flaps up and 5g with the flaps down (figs. 7(a) and 7(b)). Damage which occurred at the 5° attitude (fig. 8) was more severe than that which was encountered at the 9° landing attitude. Ditchings at the 1° landing attitude resulted in the model diving with the flaps either up or down. The scale-strength fuselage bottom sustained the greatest amount of damage at the 1° landing attitude. The landing runs were shorter and decelerations higher at the 1° attitude than at any other attitude, indicating this attitude as the most severe condition.

Effect of Flaps

When the flaps were down, they contacted the water near the beginning of the run and the scale-strength connections failed. If the flaps were installed so that they rotated toward a neutral position upon failure of the scale-strength connections, an undesirable nose-down moment was produced; whereas, if the flaps became detached from the model, smooth runs were obtained. When the flaps were up, the model ran smoothly at all conditions tested except when damage was simulated at the 1° landing attitude; here a dive resulted.

The model tests resulted in lower decelerations and less damage in the landings with flaps down (even when a nose-down moment occurred) than in the landings with flaps up (see table I and figs. 4, 5, and 7). Consequently, a flaps-down condition is preferable for a ditching.

Effect of Damage

Some damage occurred during all ditchings with scale-strength bottoms installed. The damage eliminated all tendency to trim up and at some conditions produced a greater tendency for the model to nose in or dive. When damage occurred the landing runs were shorter and the decelerations higher than when no damage was present.

Effect of Attitude and Speed

A decrease in the landing attitude and the accompanying increase in speed contributed to higher decelerations, generally shorter runs, more damage, and more violent ditching behavior (see table I). A nose-high attitude of about 9° with the landing flaps full down is considered best for a ditching. The lowest longitudinal decelerations and least amount of damage were obtained at this condition, although the damage was sufficient to cause the fuselage to leak substantially.

CONCLUSIONS

From the results of the calm-water ditching investigation of a $\frac{1}{15}$-scale model of the Convair-Liner airplane, the following conclusions were drawn:

1. The airplane should be ditched at a nose-high attitude of about 9° with the landing flaps full down.

2. The flaps will fail on contact. If they are torn away, the airplane will probably make a smooth run with a maximum deceleration of about 3g. If they rotate toward neutral but are not torn away, the fuselage will run deeper and the maximum deceleration will be about 4g.

3. The fuselage bottom will probably be damaged enough to leak substantially.

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TABLE I

SUMMARY OF RESULTS OF DITCHING INVESTIGATION OF A $\frac{1}{15}$-SCALE

DYNAMIC MODEL OF THE CONVAIR-LINER AIRPLANE

[All values full scale; gross weight, 43,500 lb]

Landing attitude (deg)	Flap setting	Landing speed (mph)	Maximum longitudinal deceleration (g)	Length of landing run (ft)	Motions of the model
Undamaged model					
9	Up	121	$3\frac{1}{2}$	600	Ran smoothly
9	Full down[1]	94	$1\frac{1}{2}$	360	Oscillated, ran deeply
9	Full down[2]	94	1	400	Ran smoothly
5	Up	140	3	660	Trimmed up, ran smoothly
5	Full down[1]	101	5	165	Dived
5	Full down[2]	101	$1\frac{1}{2}$	380	Ran smoothly
1	Up	189	4	840	Trimmed up, ran smoothly
1	Full down[1]	115	6	170	Dived
1	Full down[2]	115	5	350	Trimmed up, ran smoothly
Scale-strength fuselage bottom installed and main landing-gear doors removed					
9	Up	121	6	300	Ran smoothly
9	Full down[1]	94	4	200	Ran smoothly, ran deeply, nosed in
9	Full down[2]	94	3	300	Ran smoothly
5	Up	140	8	265	Ran smoothly, ran deeply
5	Full down[1]	101	5	200	Dived
5	Full down[2]	101	$3\frac{1}{2}$	300	Ran smoothly
1	Up	189	Above 8g max. of instrument	225	Dived
1	Full down[1]	115	7	165	Dived

[1]The scale-strength flap connections failed and the flaps rotated toward the neutral position.

[2]The scale-strength flap connections failed and the flaps became detached from the model.

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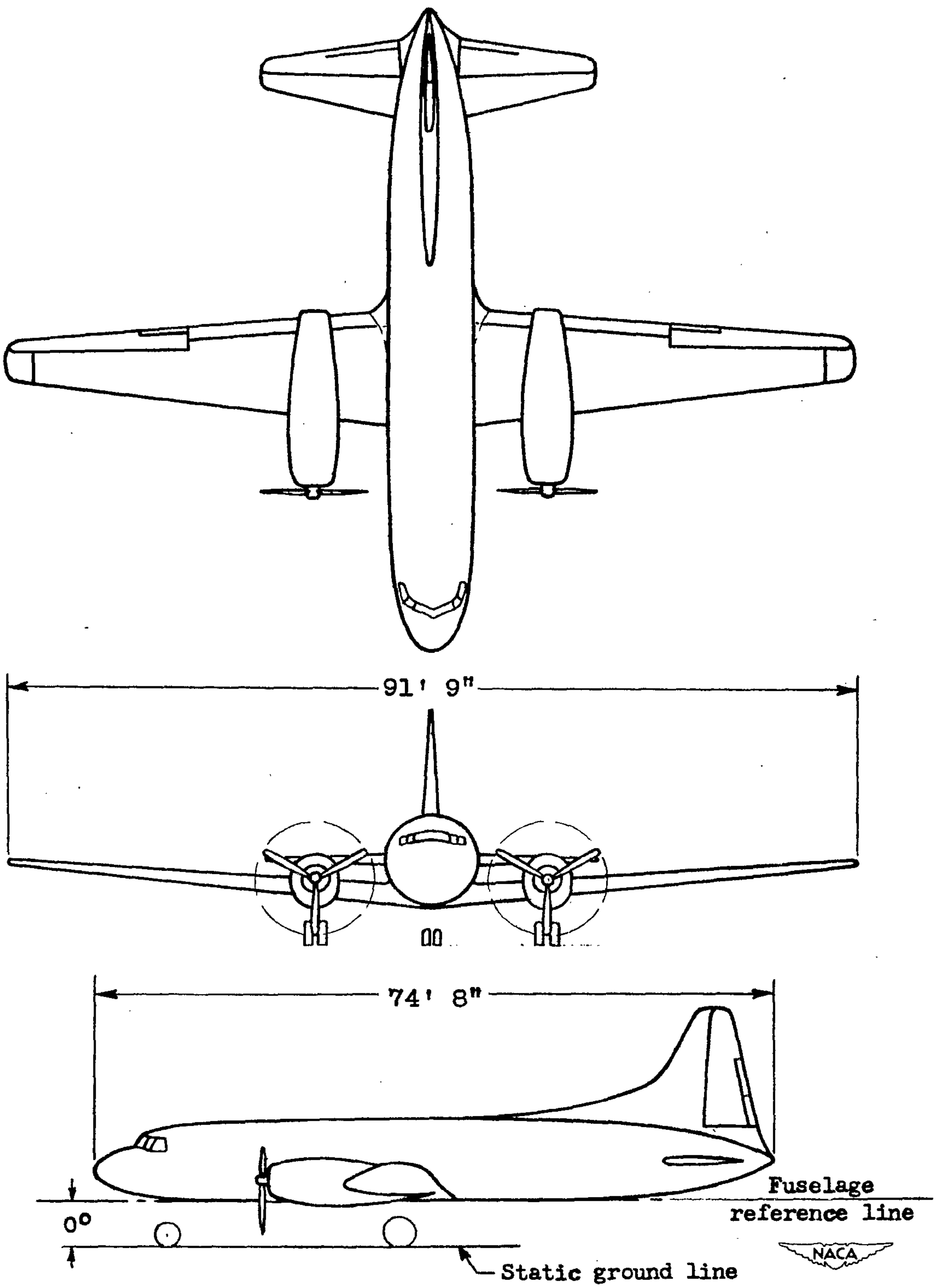
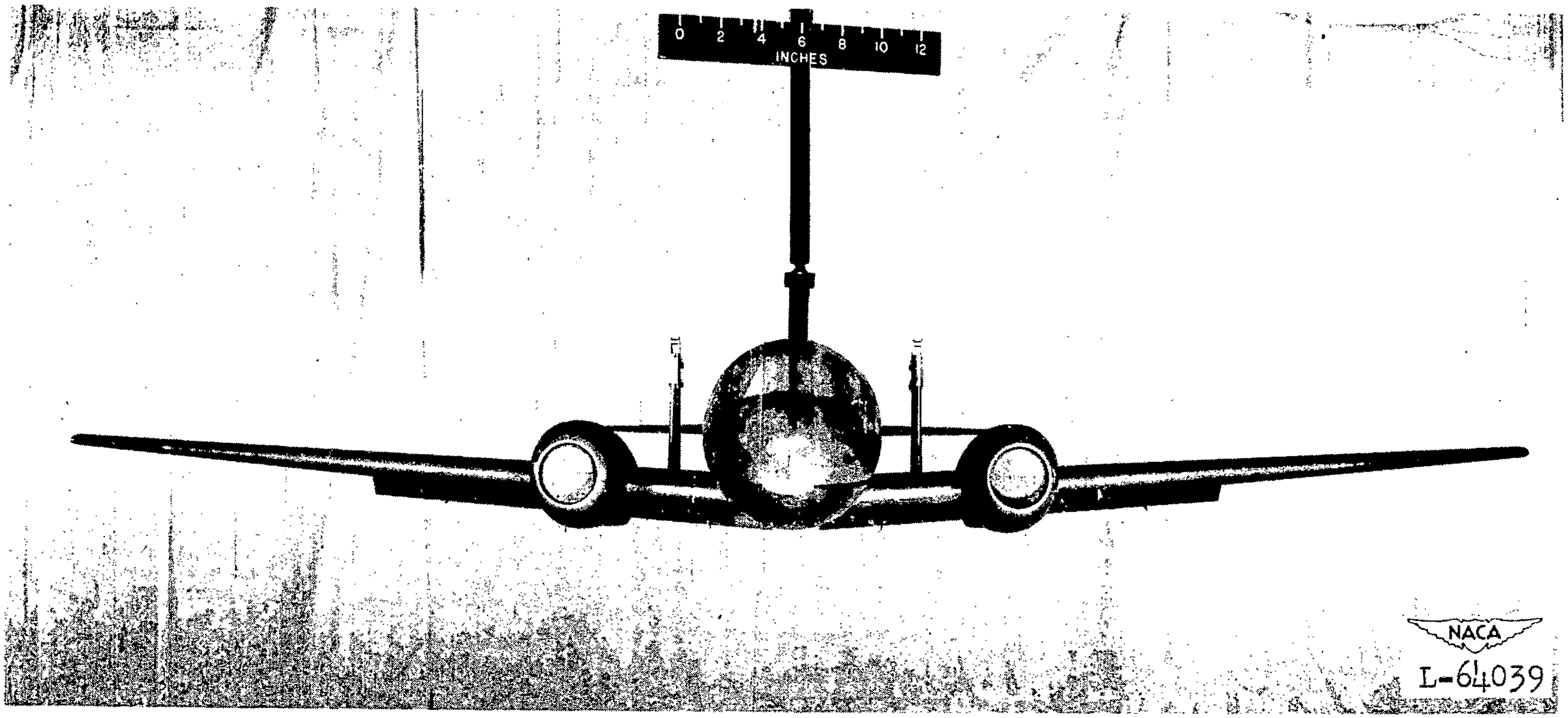
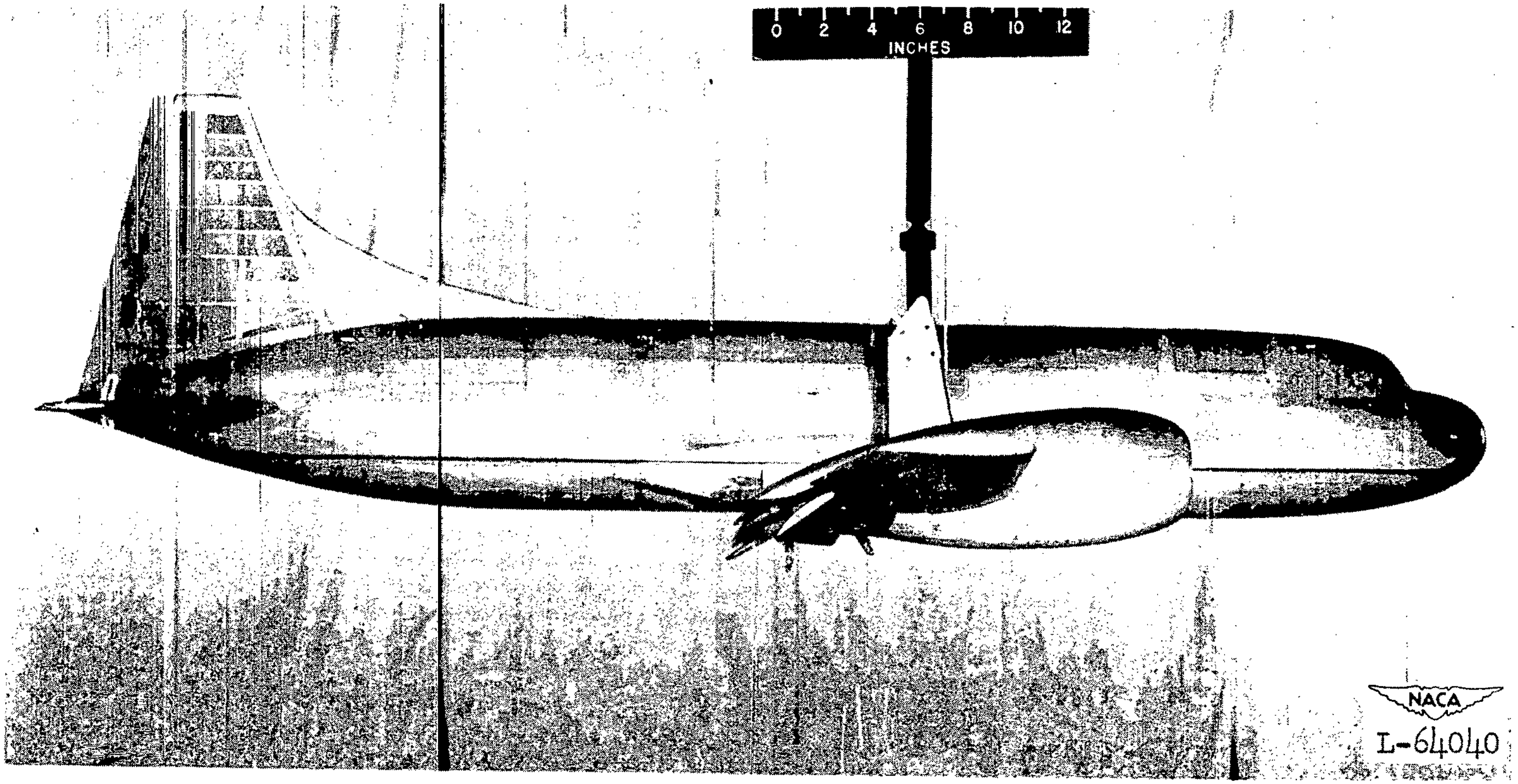


Figure 1.- Three-view drawing of the Convair-Liner airplane.



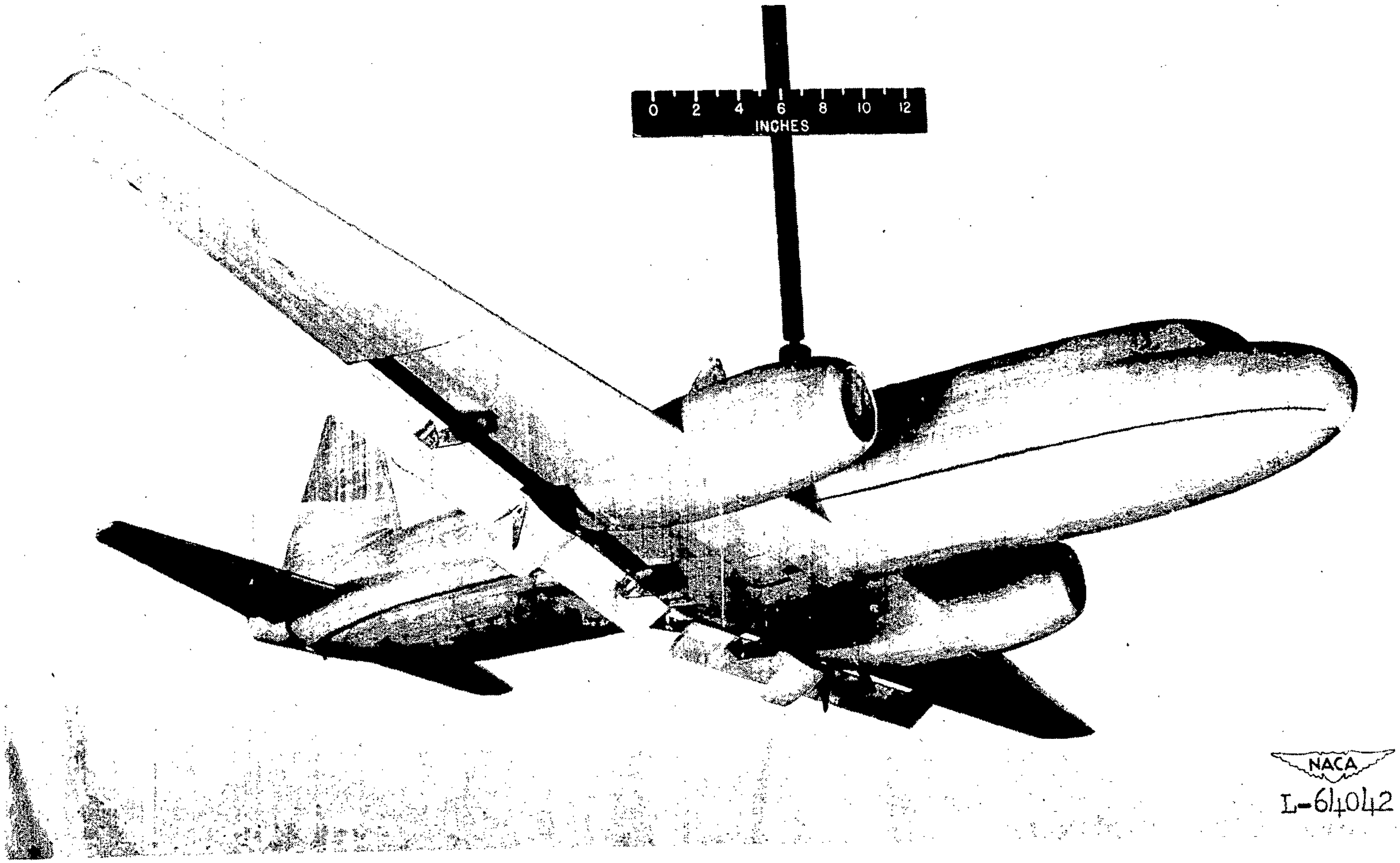
(a) Front view.

Figure 2.- The Convair-Liner ditching model.



(b) Side view.

Figure 2.- Continued.



(c) Three-quarter bottom view.

Figure 2.- Concluded.

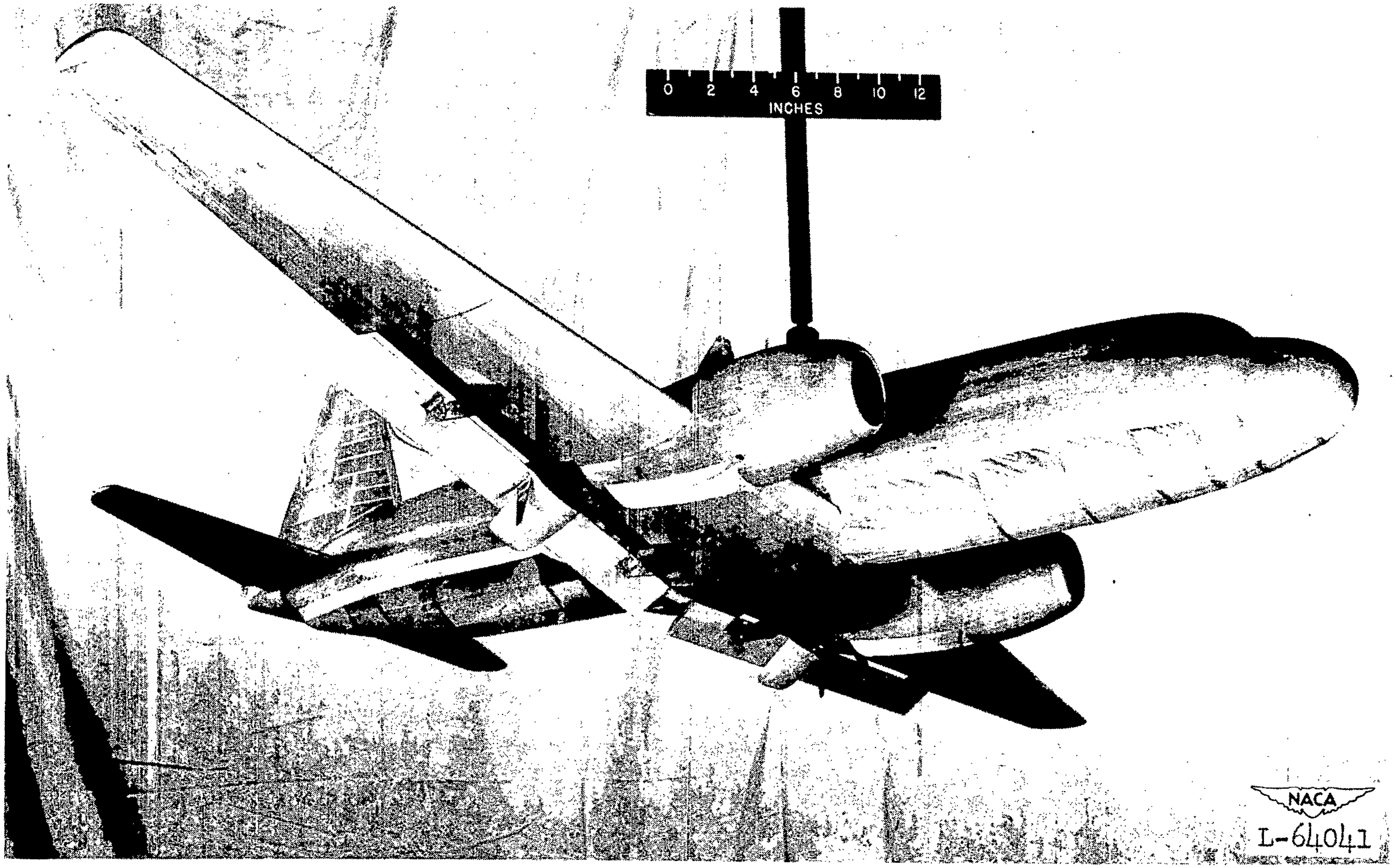
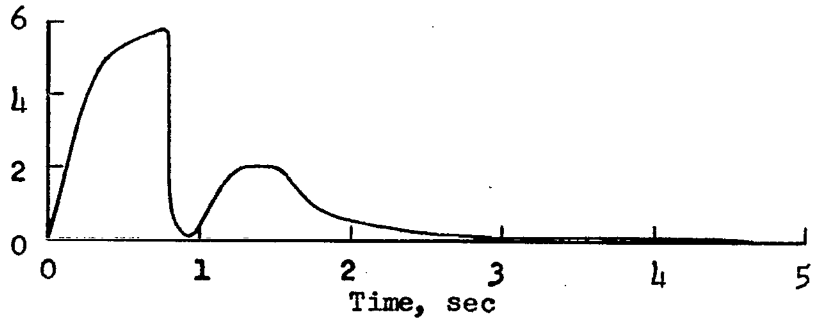
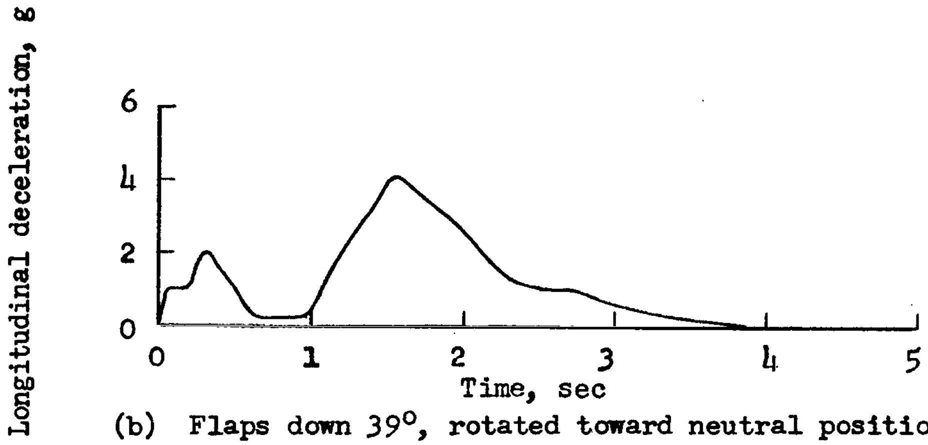


Figure 3.- Model with scale-strength fuselage bottom installed and main wheel doors removed.

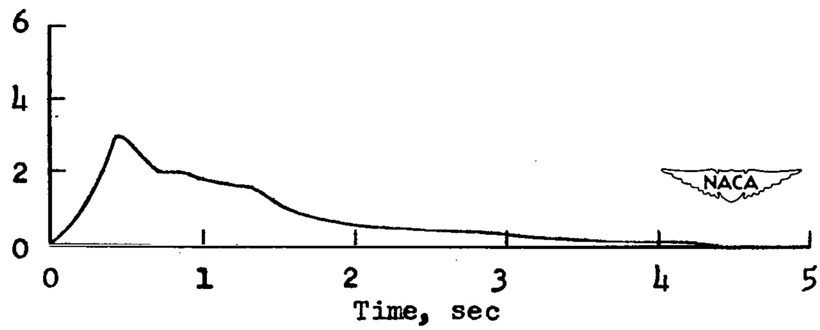


(a) Flaps up; landing speed, 121 mph.



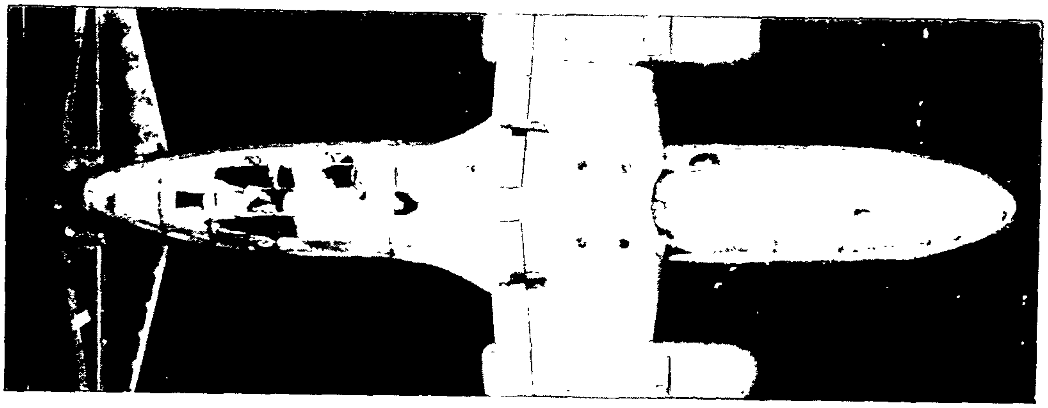
(b) Flaps down 39°, rotated toward neutral position

(b) Flaps down 39°, rotated toward neutral position when scale-strength flap connections failed; landing speed, 94 mph.



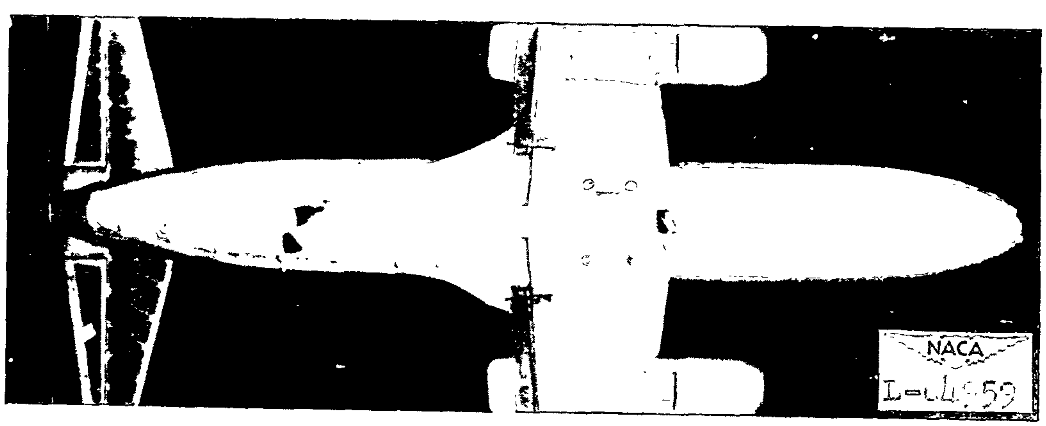
(c) Flaps down 39°, became detached from model when scale-strength flap connections failed; landing speed, 94 mph.

Figure 4.- Longitudinal decelerations for typical ditchings with scale-strength fuselage bottoms installed and main landing-gear doors removed. Landing attitude, 9°. All values are full-scale.



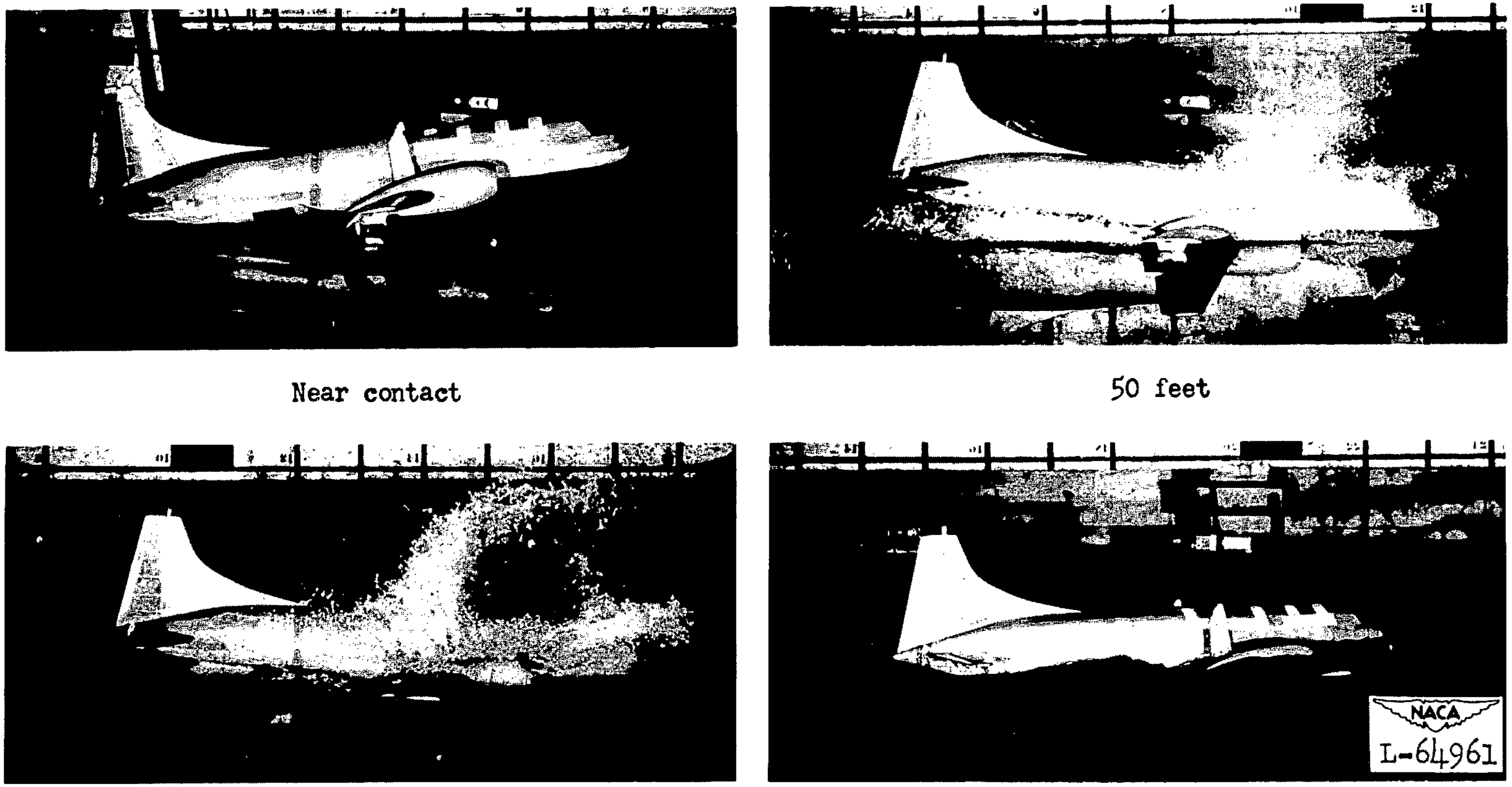
(a) Flaps up.

(b) Flaps down 39°, rotated toward neutral position when scale-strength flap connections failed.



(c) Flaps down 39°, became detached from the model when the scale-strength flap connections failed.

Figure 5.- Typical damage which occurred to the scale-strength fuselage bottoms at the 9° landing attitude.



Near contact

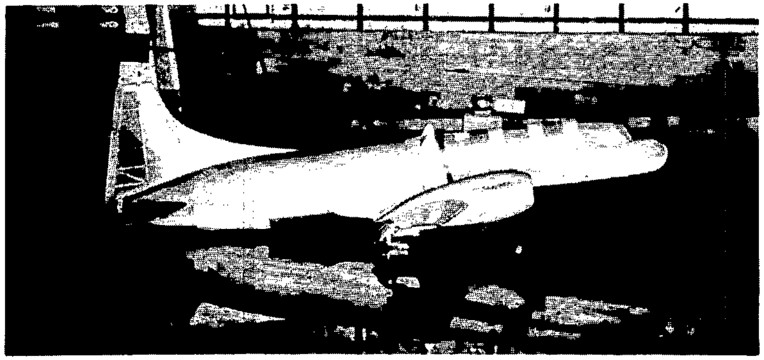
50 feet

135 feet

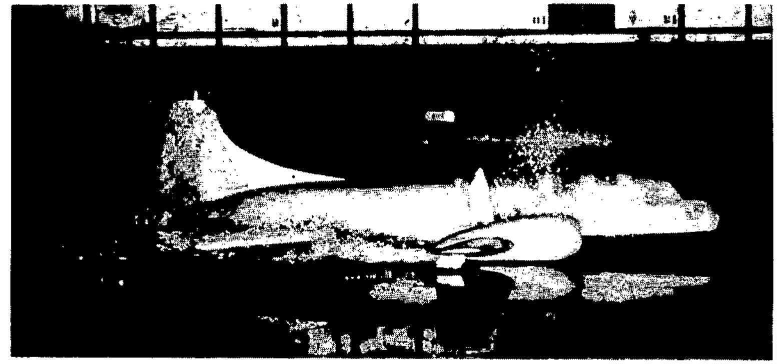
200 feet

(a) Flaps down 39°, rotated toward neutral position when scale-strength flap connections failed.

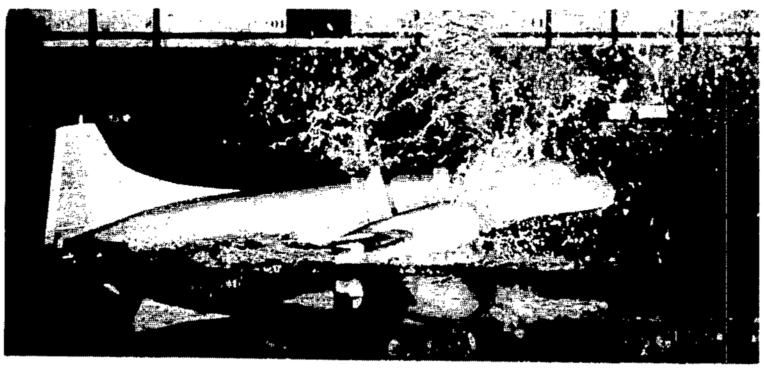
Figure 6.- Sequence photographs of model ditchings with scale-strength fuselage bottoms installed; landing attitude, 9°. All values are full-scale.



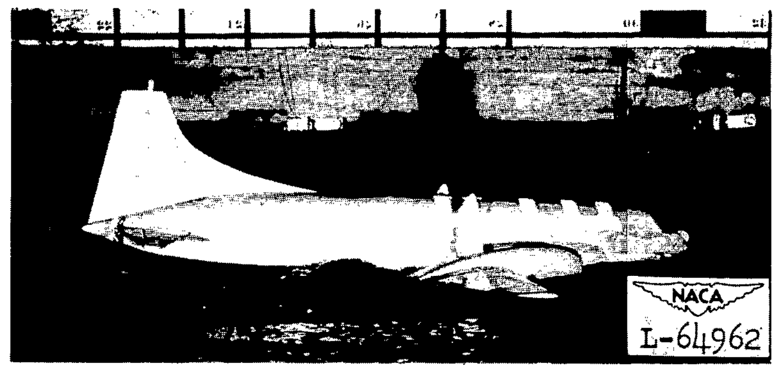
Near contact



50 feet



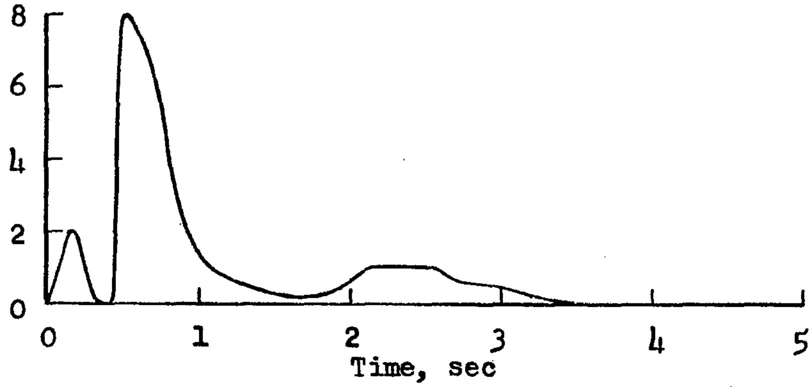
150 feet



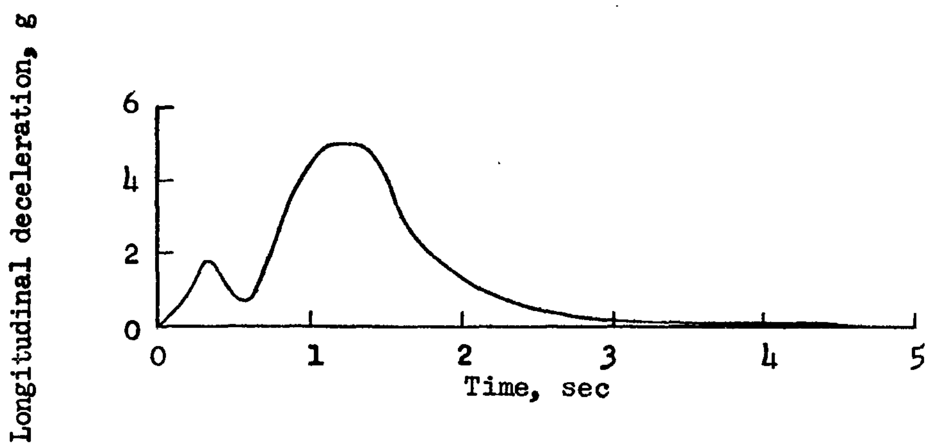
300 feet

(b) Flaps down 39°, became detached from the model when scale-strength flap connections failed.

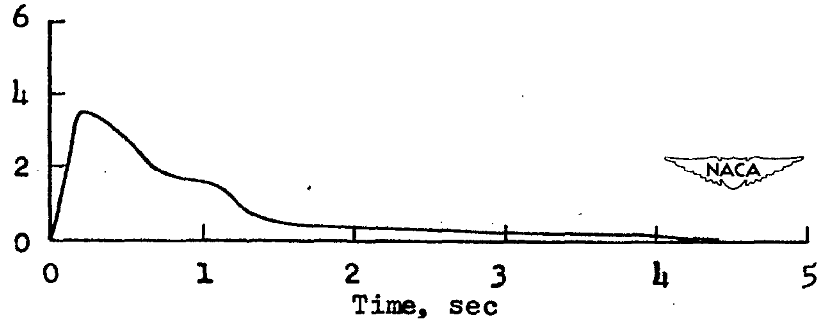
Figure 6.- Concluded.



(a) Flaps up; landing speed, 140 mph.

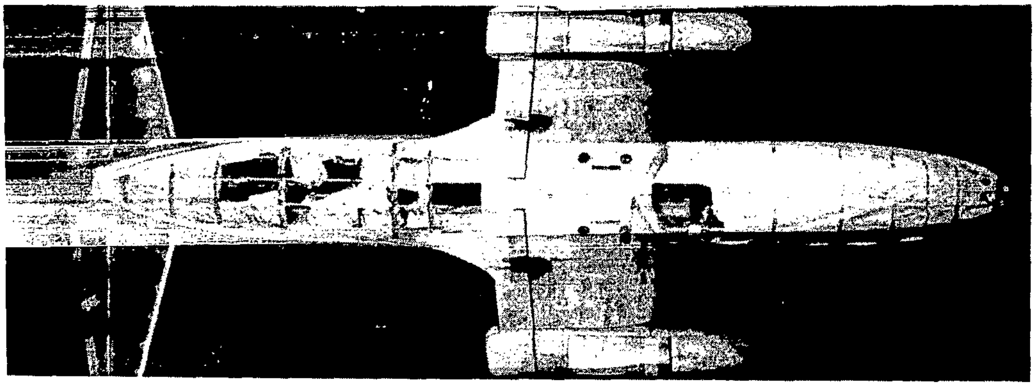


(b) Flaps down 39°, rotated toward neutral position when the scale-strength flap connections failed; landing speed, 101 mph.

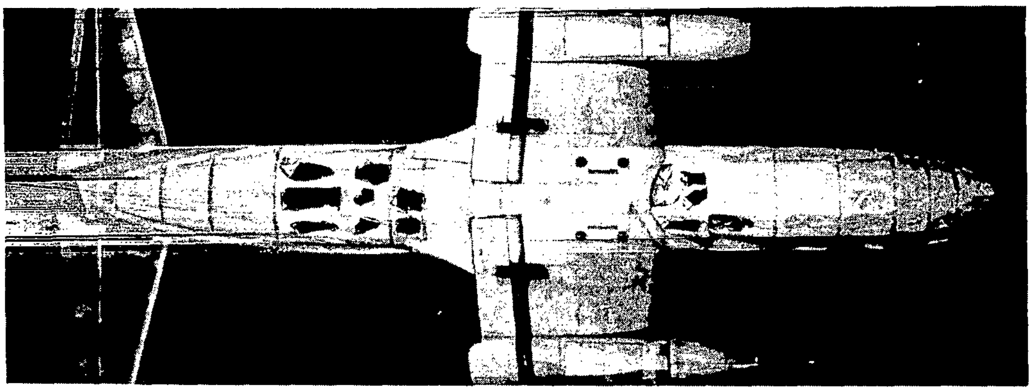


(c) Flaps down 39°, became detached from model when scale-strength flap connections failed; landing speed, 101 mph.

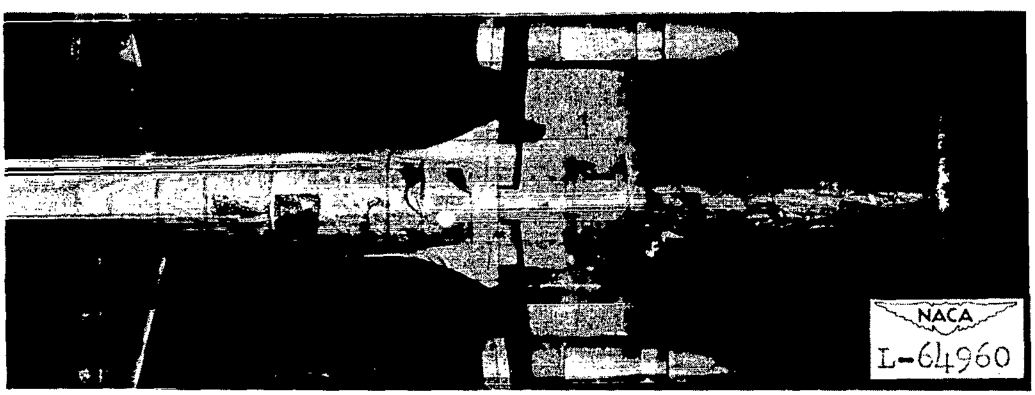
Figure 7.- Longitudinal decelerations for typical ditchings with scale-strength fuselage bottoms installed and main landing-gear doors removed. Landing attitude, 5°. All values are full-scale.



(a) Flaps up.



(b) Flaps down 39°, rotated toward neutral position when scale-strength flap connections failed.



(c) Flaps down 39°, became detached from the model when the scale-strength flap connections failed.

Figure 8.- Typical damage which occurred to the scale-strength fuselage bottoms at the 5° landing attitude.